NATURAL RESOURCES CONSERVATION SERVICE
VIRGINIA TECHNICAL NOTE

Forestry #2

FOREST STAND IMPROVEMENT METHODS

Forest Stand Improvement (FSI) is a silvicultural method used for managing a forest for specific objectives. Two of the most common objectives for FSI are increasing forest productivity and improving forest quality. These objectives are true whether the forest is used for lumber production (sawtimber), pulpwood, or specialty products, such as Christmas trees, nuts, syrup, boughs or cones.

Young stands of timber are often over-grown with undesirable vegetation. If pines are the favored species, hardwoods are considered undesirable along with grasses, weeds and shrubs. If hardwoods such as oaks, walnut, pecan, or maple are favored, then pines, and other hardwoods, such as cedar and sweetgum are the unwanted species along with grasses, weeds and shrubs. Undesirable species compete for water, light, nutrients and space, thereby restricting the growth and development of the desirable species. It may take two or more FSI treatments over the life of the forest to adequately control competition.

Young trees exhibit vigorous growth. The cross section of a young tree will have wide growth rings and its diameter expands quickly. As trees grow they start to compete with each other for light and space. When tree crowns begin to touch at this intermediate stage, diameter growth declines. Tree rings become narrower as competition increases. If the competition is not removed (thinned), tree growth remains slow to maturity, the tree may even die. If the competing trees and other plants are thinned, the competition for light, space, water and nutrients is reduced and the remaining, or leave, trees once again exhibit vigorous growth until competition once again is encountered.

An increment core can diagnose tree ring growth. An instrument called an increment bore removes a cylinder of wood from the center of the tree to the bark. This cylinder is the increment core for the tree. Tree rings are easily seen and can be measured and counted. See Figure 1 for an example of an increment core and tree growth response from thinning.

TREE GROWTH RESPONSE TO THINNING

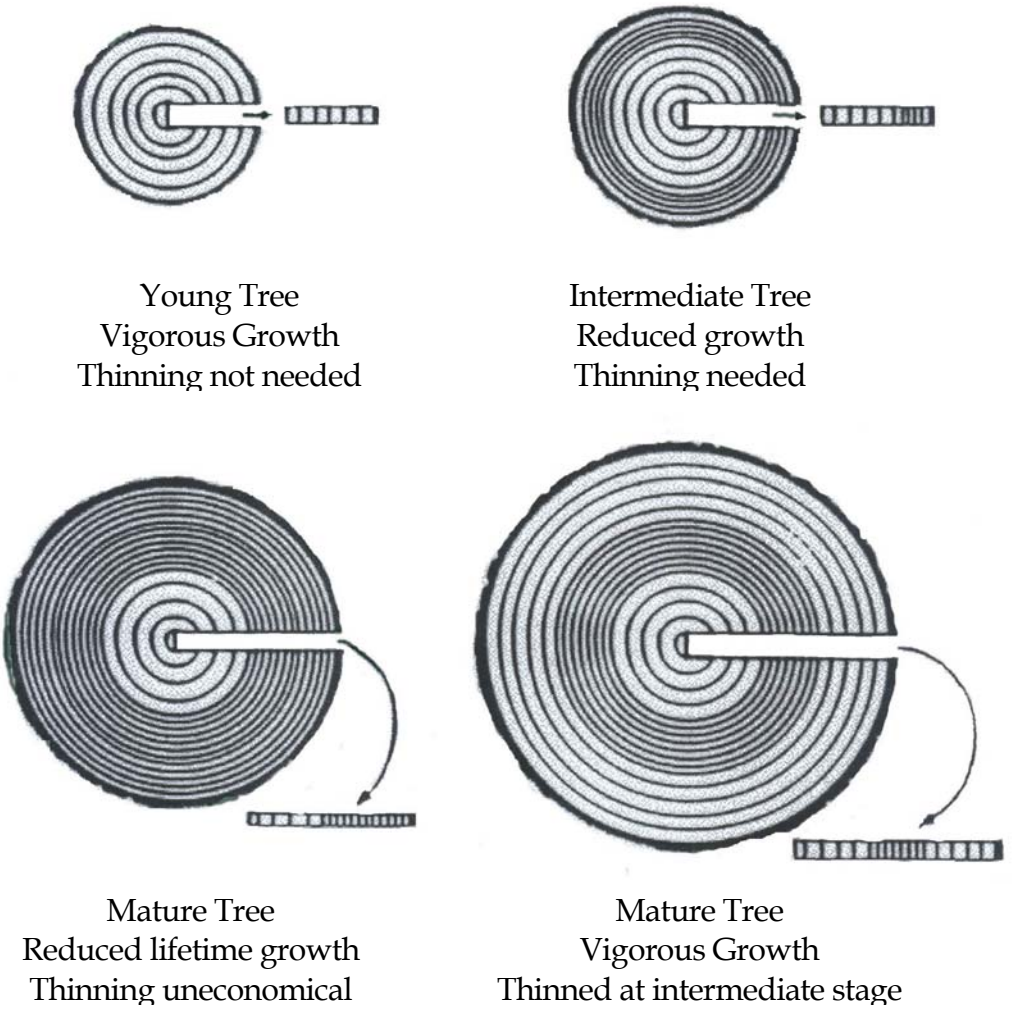


Figure 1. Tree cross sections and increment cores illustrating growth response from no thinning and thinning treatments. Notice the diameter of the mature tree after thinning compared to the mature tree without thinning treatment.

There are many techniques for accomplishing forest stand improvement. Use of the different techniques depends on the purpose of the treatment, species favored, age of the trees, site index (measures the ability of the soil to grow trees), size of stand to be treated, amount of competition, and cost of labor, equipment and materials. Young stands are often treated mechanically while cutting and girdling are used in older stands. Herbicides can be used at any stand age.

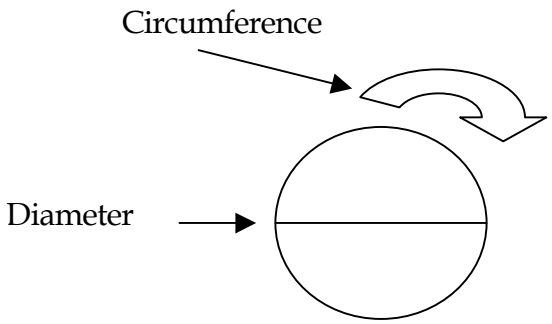
Site quality of an area can help determine whether a forest stand improvement should be made. Site quality is measured in terms of "site index", a species -specific measurement, in feet, that combines tree height with age; and is also a good indicator of the soil's potential to grow trees. Site index takes into account the average height of the largest trees (called dominant trees for the tallest trees and co-dominant for the trees just below the height of the dominant trees) with a base age, usually 50 for pines and 80 for hardwoods.

For example, the site index for loblolly pine, base age 50, can range from 60 to 110 feet. Therefore in a 50 year-old forest of loblolly pines, the tallest trees on the lower site index average 60 ft in height while on the higher site index areas the trees are on average 110 feet in height or 45% taller and probably contain much more merchantable wood.

Areas with a higher site index should be thinned before considering areas with a lower site index. Growth response is greater in higher site index areas. Trees on low site index areas may not respond to thinning at all. Usually trees found on low site index areas are not desirable species and the cost for a forest stand improvement will not be covered in subsequent growth.

WOODY PLANT CONTROL

One of the most common purposes for FSI is woody plant control. Woody plant control can be associated with weeding a garden. In a garden, weeding eliminates the undesirable equated plants while leaving the desirable plants. Desirable trees (also called released or leave trees) require a certain amount of space (trees/acre) to form properly. The amount of space depends on the tree's age or size. For trees less than 4" dbh (dbh is **d**iameter at **b**reast **h**eight which is the diameter of a tree, measured with a calibrated ruler or tape, at 4 ½ feet above the ground), the released trees should average no farther than 12 feet apart or 304 trees/acre. Trees 4 to 8 inches dbh should be released at intervals of 12 to 15 feet or 304 to 194 trees/acre.



Circumference is the linear distance around a circle. Diameter is the linear distance through the widest part of a circle. dbh is measured at 4 ½ feet above the ground with a tape calibrated with a diameter measurement. The tape is stretched around the tree's trunk (circumference).

Figure 2. Circumference and diameter measurements.

Unwanted hardwood trees, shrubs, vines, weeds or grasses may be removed or controlled by a number of techniques. These include chemical (herbicide) and mechanical treatments or a combination of the two methods. The methods may be classified as (a) Individual-stem treatments (with or without herbicides); (b) Foliar spraying; and (c) Soil applications of herbicides.

Individual-stem treatments are usually best where desirable trees are intermingled with weed or cull trees and shrubs and need to be released from competition for sunlight, soil moisture and available nutrients. Soil applications are especially effective on sandy soils. See Table 1 for methods for woody plant control.

Sprays may drift and harm desirable plants downwind of treated areas. Foliar spraying using aircraft, mist blowers or ground equipment to apply chemicals is best adapted to large contiguous areas, remote from farms and communities. This method is fast and effective, but there is danger to crops from the drift of the herbicide vapors, unless strict precautions are taken. Foliar spraying may also be used to kill kudzu, poison ivy and other undesirable noxious vegetation.

For all above treatment methods, use an appropriate chemical registered and approved for use by EPA. Refer to the current Virginia Cooperative Extension Pest Management Guide for Horticultural and Forest Crops or the herbicide use sheets found in the Virginia Department of Forestry internet homepage at www.dof.state.va.us. Refer to the label for selected herbicide for optimum season for treatment, dosage and applications instructions. Apply according to label directions and safely precautions. Specific pesticide recommendations will be obtained from personnel who are licensed by the Virginia Department of Agriculture and Consumer Services in the Forest Pest Control Category in accordance with Virginia's pesticide laws and regulations.

TABLE 1 - Methods for Woody Plant Control

Hand Crew Methods	Effective Size of Target Stems	Equipment
directed foliar sprays	up to 6 feet tall	backpack sprayer
streamline basal sprays	up to 2 inches dbh	backpack sprayer with handgun
soil spots by grid	up to 10 inches dbh	spotgun or gunjet with straight stream spray tip
basal soil spots	all sizes	spotgun or gunjet with straight stream spray tip
injection	all sizes greater than 1 inch dbh	tubular tree injector, hypo-hatchet, axe or hatchet with spray bottle
stump sprays[1/]	all sizes	backpack sprayer
girdling[2/]	All	axe or mechanical girdler

Ground Machine Methods	Equipment
foliar spray	Crawler, skidder, farm tractor, all-terrain vehicle equipped with spray system
pelleted or granular	Crawler, skidder, farm tractor, all-terrain vehicle equipped with spreader with spinning disc or forced-air blower

Aerial Method	Equipment
foliar spray[3/]	Helicopter
granular or pelleted	Helicopter

[1] Stump spraying is used to reduce sprouting. Except for species such as red maple, ash and chestnut oak, stumps larger than 12" dbh are not likely to sprout.
[2] Girdling without a herbicide is only effective for easy-to-kill species or trees larger than 12" dbh.
[3] Aerial spraying is used for all sizes of major hardwood species. It is an appropriate method for larger tracts where brush is dense and terrain is difficult.

PRE-COMMERCIAL THINNING

Pre-commercial thinning is needed in forests where the stand of desirable trees of unmerchantable size is overstocked, crowding out desirable trees in number and space. Pre-commercial and unmerchantable mean that the trees are too small to sell at a profit. Pre-commercial thinnings are applied to young stands, 2 to 4 inches dbh. Such stands are classed as being in the sapling stage (trees 3 feet or more in height and under 4 inches dbh). The practice is particularly needed in young, even-aged stands which have seeded in

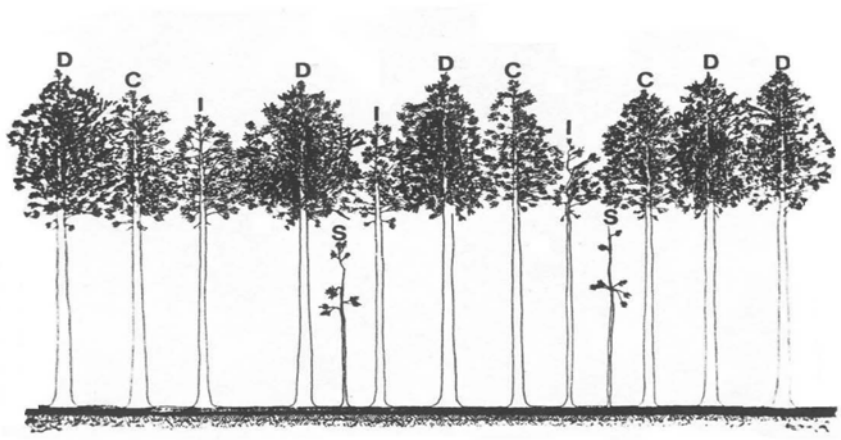
thickly in old fields, burned stands and cut-over areas where diameter growth is negligible and a stagnated condition has resulted.

Select desirable trees on the basis of species, form, vigor and crown development. Dominant trees have crowns at the highest level in the forest while co-dominant trees have crowns just below the dominant trees. These two crown classes denote the most vigorous trees and are the ones to be released. Diseased, deformed, short, weak crowns, and otherwise defective trees should be cut down. Figure 3 shows the various crown classes for trees.

CROWN CLASSES

D = Dominant, C = Co-dominant, I = Intermediate, S = Suppressed

Figure 3. In a thinning operation to improve forest stand productivity intermediate and suppressed trees are removed, also any dominant or co-dominant trees that are dead, diseased, poorly formed, or over-mature will be removed.



Pre-commercial thins are usually accomplished with cutting. The cutting tool depends on the size of the trees, shrubs and vines to be removed. For removal of vegetation 1 ½ inches or less in diameter, use one or more of the following: rotary mower, pruning shears (two handed types), machetes, safety bush (Swedish Bush) axes, woodman's pal or brush hooks. For vegetation between 1 ½ and 4 ½ inches in diameter, use single and double-bladed axes, brush hooks, or power-driven brush saws. If the vegetation is over 5 inches in diameter, use one-man crosscut saws, frame or bow saws, one-man power chain saw, or portable, circular power saws. A pike pole handled by a second person is used to reduce the chance of trapping the saw. While cutting, the pole is pushed against the upper bole of the tree to prevent pinching of the saw and eliminating the need for undercutting.

For larger tracts, a drum chopper pulled behind a crawler tractor with a KG (shearing) blade is useful. Leave rows of trees approximately 3 feet wide in a "checkerboard" pattern. This results in a grid of trees on approximately 12 x 12-foot spacing.

If mechanical control of undesirable hardwoods is used in a pre-commercial thinning, sprouting may be reduced or eliminated by treating the stumps with an approved herbicide. However, where a single tree of a sprout clump is the desirable leave tree, chemical control of stump sprouts cannot be used since it may harm the single tree that is left for the new forest.

OPTIMUM SEASONS FOR THINNING

PINE

In pine stands, pre-commercial thinnings should be made during the late fall and winter months – from October through March, unless wet conditions limit equipment operation. Thinning in the fall and winter reduces the possibility of insect infestation, particularly the pine bark beetles which can devastate a stand. However, if the fungus Fomes annosus is the primary threat, summer thinning from May to August is preferable.

HARDWOODS

Generally, it is best to make pre-commercial thinnings in hardwood types during mid-summer because less sprouting occurs than in other seasons.

SLASH DISPOSAL

The slash (cut tops, limbs, boles and stems) left in pre-commercial thinnings can remain where they fall. They may be windrowed (bulldozed into piles) if there is a high fire threat. However, bulldozing often removes too much topsoil which may affect long term productivity. To reduce insect damage, larger stems, limbs and boles should be pulled away from leave trees.

Pine slash has a high flammability for about two years, but by the end of three or four years, decomposition has advanced to the extent that the needles and most of the small limbs have fallen and the sapwood is completely decayed. By the end of five years, decay has reduced the fire hazard to zero.

Hardwood slash has a much lower flammability than pine during the first two years after cutting because the leaves decay more quickly. Thereafter, the wood decays at about the same rate as pine so that, by the end of five years, the fire risk from slash is negligible.

SPACING AFTER THINNING

Spacing of leave trees should be wide enough to permit fast growth until they are of sufficient size in diameter and height to yield useable or saleable (commercial) products and the stand is ready for an intermediate cutting (commercial thinning). Some room should be left for crown spread; however, the trees should be left close enough to fully utilize the growing space until the first commercial thinning is made.

SOUTHERN YELLOW PINES, WHITE PINE AND MIXED PINE-DESIRABLE HARDWOODS

The number of released trees in stands averaging 2 –to- 4 inches dbh should range from 436 (2”) to 304 (4”) trees/acre. The resulting spacing would be 12 x 12 Feet for the 2” trees to 10 x 10 feet for the 4” trees. The trees left after thinning should be far enough apart so that 3 to 8 years, depending on site quality, will be required for their crowns to grow together. However, they should be able to close crown canopy and fully occupy the site in 5 to 10 years.

SOUTHERN APPALACHIAN HARDWOODS

Thinning is not recommended until the trees are over 4” dbh, unless most of the trees are growing at about the same rate and show evidence of stagnation. In yellow poplar stands this rarely happens since individuals assert dominance at an early age. However, if pre-

commercial thinning is indicated by the condition of the stand, the number of released trees should range from 304 (4" dbh) to 436 (2" dbh) per acre.

When thinning sprouts, removal of one of two V shaped sprouts may kill the other. Therefore U-shaped sprouts should be selected where only one of two is to be removed.

When red oak regeneration is desired and only small oak seedlings are present, a special "oak shelterwood" system that eliminates understory/midstory trees with herbicides, can be applied. Sufficient light is provided to the forest floor for small oak seedlings to develop into large seedlings in about 10 years.

SPRUCE-FIR

The number of released trees should range from 436 (4" DBH) to 680 (2" DBH, or 8 x 8 foot spacing) per acre. Competing hardwoods should be removed. Red spruce and Fraser fir should be favored.

FOREST PRODUCTS (FROM INTERMEDIATE THINNINGS OR FOREST REMOVAL)

INTERMEDIATE THINNINGS

Intermediate thinnings or cuttings is the removal of trees from a stand between the time of planting and the final harvest or removal of all remaining trees. Start intermediate cuttings in a stand at the earliest age that the cutting will provide sufficient wood products to make a profitable operation. Site index curves are a useful reference to show growth characteristics and height potentials by age. Maintaining proper spacing and stocking is most important for trees to grow quickly to economic and/or biological maturity.

Spacing Guide

Pine Stands

The recommended spacing for pine stands uses a "D+X" guide. D+X is an expression of linear distance in feet between leave trees. D+X is a way to express $(D+X)^2$, the growing space required by a tree for normal growth for a given number of years. "D" equals the diameter of the leave tree in inches at dbh. "X" is an added constant to give normal growth space for the leave trees. In most cases "X" will be 6 in southern pine. Therefore, the D+X spacing of 10" trees will be 10 + 6 or 16 feet. This means that $(D+X)^2$ would be 16 X16 or

256 square feet, the growing space made available for the crown of a 10" tree to grow for a given number of years.

Another method for determining spacing between trees is NRCS Woodland Information Stick which relates the size of a tree, in terms of DBH, to the space available for it to grow. The Woodland Information Stick has three tables printed on it related to spacing. Table 1 is a thinning guide, Table 2 is spacing and number of trees per acre and Table 3 is the relationship of tree spacing to basal area per acre. To use the Stick, it is important to remember that D is equal to a value in feet obtained by measuring a tree's DBH closest to the nearest inch, and expressing it in feet; e.g. if DBH = 4 inches, then D = 4 feet. To use D+X in a stand with 10 inch DBH trees, and X = 6 as above, D+X = 16 feet, the leave trees should be about 16 feet apart for optimal growth.

In practice, the spacing must necessarily be in terms of diameter and linear distance, rather than square feet. To determine the desired square foot spacing, trees should be considered in groups of three or more, arranged in compact geometric figures with several outside trees spaced approximately D+X feet apart. Mark trees in excess of D+X spacing for cutting. Always select trees of the poorest quality and the least desirable species for cutting.

Table 2 shows the relationship of tree spacing to basal area per acres. Basal area is the cross section of a tree stem at DBH expressed in square feet. Optimum stocking is usually about equal to the Site Index when trees are 8 to 10 inches in diameter. Example: SI 90-optimum stocking is 90 square feet per acre.

Using the D+X guides and the Woodland Information Stick, Table 2 shows the optimum stocking rates after thinning for timber production.

Table 2 – Optimum Stocking Rates After Thinning For Timber Production

Average Diameter (DBH) in inches	D+X Spacing	Average Spacing Between Trees	Basal Area Per Acre	Number of trees Per Acre
Pines				
4	D+6	10	38	436
6	D+6	12	59	304
8	D+6	14	77	222
10	D+6	16	93	170
12	D+6	18	105	135

Table 2 – Optimum Stocking Rates After Thinning For Timber Production

14	D+6	20	116	109
16	D+6	22	127	90
Upland Hardwoods				
4	D+6	10	38	436
6	D+7	13	51	258
8	D+8	16	59	170
10	D+9	19	66	121
12	D+10	22	71	90
14	D+11	25	75	70

Hardwood Stands

Several factors affect the management of hardwood stands. These factors include the variety of species within a stand, varying growth rates of each species, relative vigor, and tolerance of each species to shade.

Northern red oak can only be successfully regenerated when large advance reproduction is present on the forest floor at the time of final harvest. Then any method of harvest is acceptable except single tree removal which leaves too much shade. A 'shelterwood" thinning, including removal of mid-story and understory species allows for advance oak reproduction requisite to establishing a stand after final harvest.

CUTTING CYCLES

The cutting cycle may be defined as the length of time between cuts on the same area or the planned interval between major thinning operations in the same stand. This time varies with species, stocking and site index. For well-stocked healthy stands, Table 3 is a guide for setting cutting cycles. The cutting cycles are based on the length of time required for 2 inches of diameter growth for pine and upland hardwoods and 4 inches of diameter growth for mixed cove-hardwoods and bottomland hardwoods.

Table 3 – Cutting Cycle (Years) by Site Index

Forest Type	**Site Index**							
	50	60	70	80	90	100	110	120

Southern Pine	9	8	7	6	5	5	5	-
Upland Oaks –	9	8	7	6	-	-	-	-
Mixed-Cove	-	-	14	12	10	9	8	-
Bottomland	-	-	-	-	7	6	5	4

HARVEST CUTTING

Harvest cutting is the final major harvest cutting(s) made in a stand at or near the end of a selected rotation age to insure regeneration of a new stand of trees. Apply harvest cut after the majority of the trees in the forest have reached harvest size. Harvest size is where the trees have reached economic and biological maturity. Refer to site index curves to determine if a stand has reached maturity. For example, a loblolly pine tree mature for harvest will be about 16" to 18" DBH and 45 to 55 years of age, depending on the site.

Types of Harvest Cutting

Even-aged Systems

Clearcutting, seed tree cutting and shelterwood cutting are three types of even-aged systems. These cuts remove most or all of the forest at one time and allow the area to regenerate naturally or with seeding or planting. In even-aged systems, all trees, regardless of species and planting scheme, are approximately the same age.

Clearcutting

The removal of the entire stand of trees in one cutting is called clearcutting. Clearcutting is acceptable where adequate advance reproduction is established or tree planting, coppice (sprouting) or direct seeding is planned to establish a new forest.

Clearcutting can be accomplished in patches, blocks or strips. Clearcutting is a regeneration cutting and is applicable to both pine and hardwood stands. It is applied when a stand of timber reaches financial or biological maturity, or when an immature stand is composed predominantly of low quality, undesirable, and/or cull trees of little economic value now or in the foreseeable future. Size of clearcuts should consider economics, aesthetics and needs of wildlife. At the time of harvest, all hardwood trees larger than 2" DBH (or 25 feet tall) should be cut, girdled or chemically killed. If these trees are left standing, they develop into "wolf" trees of low quality and shade the surrounding reproduction. Natural regeneration after clearcutting hardwoods comes from both seed and existing reproduction (seedlings or sprouts), provided the area has been protected from fire and grazing.

Sprouts generate one or more new stems usually from the root collar, especially if the old stem was broken during logging. New seedlings, along with stump sprouts, will provide the oak and hickory component of the stand. Yellow poplar in the new stand comes primarily from seed and stump sprouts. For adequate reproduction of hardwoods, the harvested area should be at least 2 acres in size. Larger areas are preferred to reduce the side shade effect in relation to the size of the clearcut area, to reduce logging costs and to create economical management units.

Seed Tree

Removal of the old stand in one cutting while leaving a small number of trees left singly, in small groups or narrow strips, as a source of seed for natural regeneration. Number of seed trees per acre by species are listed in the Plant Establishment Guide for Virginia and the Standard and Specifications for Forest Site Preparation (490). In addition, Virginia's Seed Tree Law specifies seed tree requirements for loblolly and white pines. After seedlings are established, seed trees should be removed within 3 years while the young seedlings are still flexible and logging damage will be small.

Shelterwood Cutting

A shelterwood cutting removes the mature timber in a series of cuttings, which extend over a period of years usually equal to not more than one-quarter and often not more than one-tenth of the time required to grow the next forest. The establishment of natural reproduction under the partial shelter of seed trees is encouraged. Harvest the seed trees within 3 years after adequate seedlings are established to prevent excess damage from logging.

Uneven-aged Systems

Cuttings such as group selection and single tree selection result in uneven-aged forests. Tree cover is continuous which favors species that are highly or moderately tolerant to shade.

Group Selection

Trees are removed in groups or strips to create openings large enough for natural regeneration with seedlings or sprouts to become established and develop normally. Openings created by cutting are usually 1/10 acre or less in size for species that are shade tolerant. For species that are moderately tolerant or intolerant to shade, opening size are kept to 1.5 to 2 times the height of surrounding trees. Openings should not exceed five times the height of surrounding trees.

This method keeps a continuous tree cover on the land and has maximum aesthetic value. This cutting favors the more shade tolerant species such as maple, oak and hickory while retarding the growth of yellow poplar, cedars, sweetgum, ashes and black walnut.

There are several drawbacks to group selection. It increases the time it takes for trees to grow to maturity or sawtimber size. Logging damage to residual trees can be high if not done properly. This method is rarely economical unless specialty wood products can be sold. However, use this method if many trees in the stand are cull or poorly formed or the stocking is of many undesirable species. Be sure that the trees to be removed have some market value and removing them will improve the stand.

Single Tree Selection

In a single tree selection cutting system only, the largest trees in the stand are removed. Success usually depends on progressively enlarging the openings through subsequent cuttings. This method is rarely used because it only favors shade tolerant species and may be successful for a few species such as pure stands of sugar maple. One severe drawback of this method is that by removing the largest diameter trees, the stand is left with

progressively lower quality trees and slower growing trees resulting in decreased stand vigor. A general rule of thumb for thinning is “Take the worst, first”.

Poorly planned thinning operations usually result in “highgrading”. Highgrading occurs when only the best trees are taken, repeatedly in a stand. Over time, the stand quality and productivity is greatly reduced. The trees left in this stand treatment are poorly formed, slow growing and usually the leftover tree species are undesirable.

Thinning methods that increase forest stand productivity are a technical skill that only professional foresters possess. Without proper training you should not attempt a thinning treatment; serious harm could be done to the stand that may take years to recover, if recovery is even possible. Serious, long-term damage to wildlife habitat as well as to stand productivity and economic value of the forest could occur with an improper thinning treatment.

SUMMARY

Forest stand improvement is a method of silvicultural treatments that improve forest productivity and quality. Some purposes of FSI are weeding out competing vegetation, removing undesirable species, eliminating dead, diseased, poorly formed or over-mature trees, and reducing competition for light, space, water and nutrients.

Several factors must be considered when designing a thinning operation including tree species, site index, stand age, size of treatment area, amount of competition, and the costs

associated with the chosen method of treatment. The overall goal of thinning is to remove undesirable trees and vegetation in favor of desirable trees. Desirable trees are vigorous, healthy, good quality trees with good form. They generally are found in the dominant or co-dominant crown classes in a forest.

Thinning operations may remove some or all of the forest. When all of the forest is removed the operation is called a regeneration cut, and the leave trees are seeds or seedlings (either planted or natural regeneration). The rule of thumb for thinning is “Take the worst, first”. With proper thinning, the forest maintains its sustainability while producing high quality trees.

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